Geo-CAPE Oceans
Coastal Ecosystem Dynamics

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Outline

- Background/Mission Overview
- Science Traceability Matrix
- Products
- Specifications
- Science & Applications

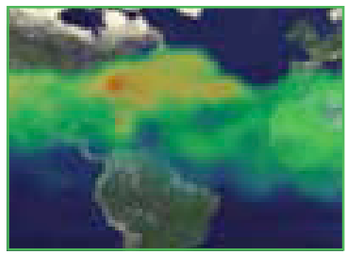
Earth Observing Satellites & Conservation NGO User Group Workshop Nov. 10, 2010

GEOSTATIONARY COASTAL AND AIR POLLUTION EVENTS (GEO-CAPE)

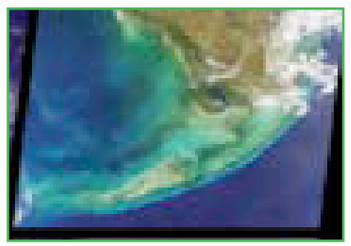
~~Launch: 2013-2016~~ **Mission Size: Medium**

Launch: >2020

Science



Identification of human versus natural sources of aerosols and ozone precursors

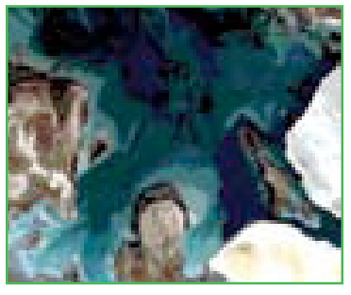


Dynamics of coastal ecosystems, river plumes, and tidal fronts

Observation of air pollution transport in North, Central, and South America

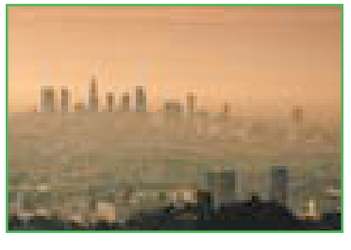
Applications Societal Benefits

Prediction of track of oil spills, fires, and releases from natural disasters



Detection and tracking of waterborne hazardous materials

Coastal health



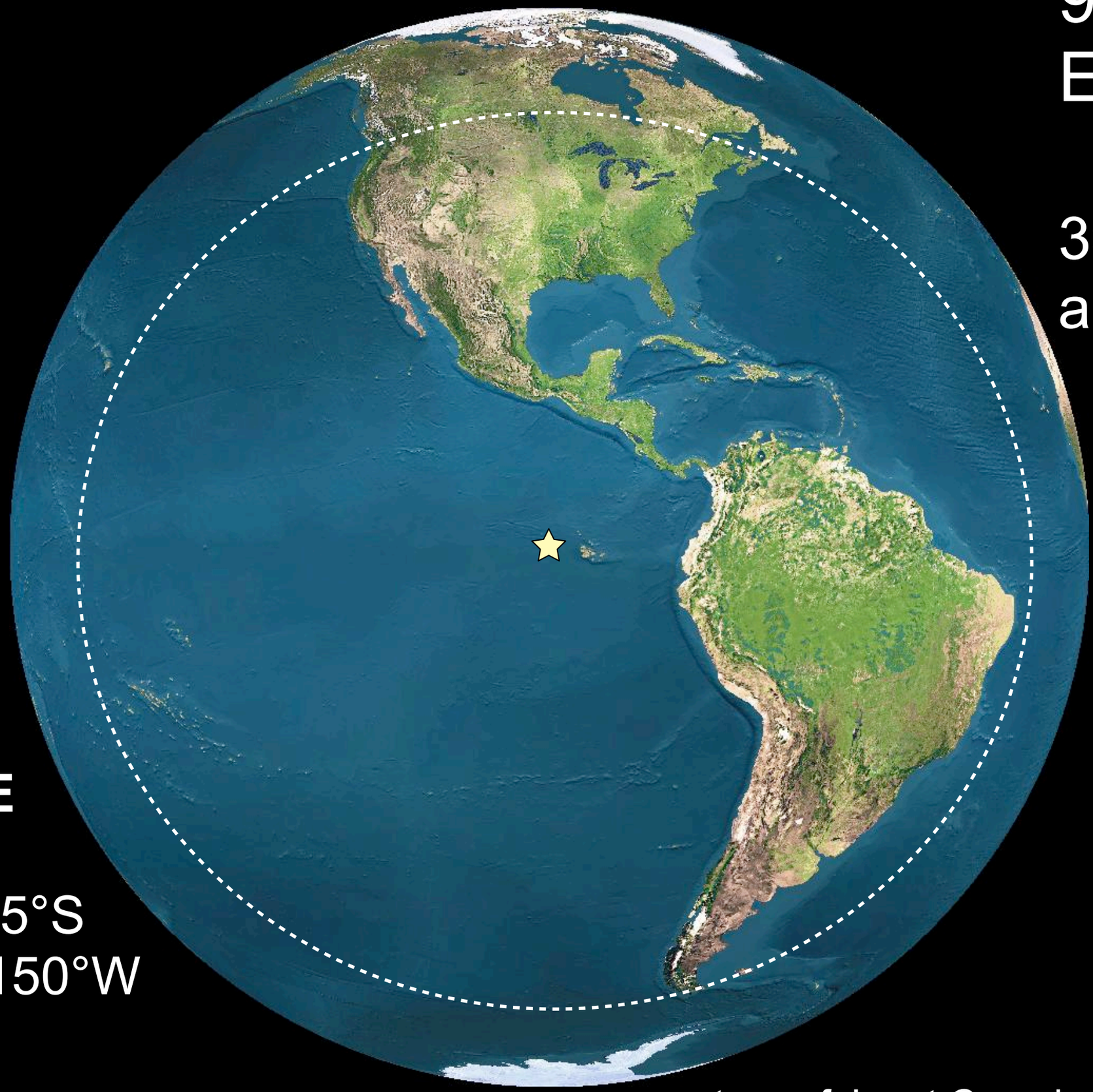
Forecasts of air quality

credit: NRC 2007

View from Geostationary orbit

95°W &
Equator

36,000 km
altitude



Geo-CAPE
Coverage
~50°N to 45°S
~35°W to 150°W

courtesy of Janet Campbell with revisions

Joint Atmospheric Chemistry - Coastal Ocean Mission

Multiple Instruments (TBD)

- UV-VIS-NIR hyperspectral sensor plus SWIR bands with high spatial resolution (250 to 400 m)
    - Primarily for Coastal Ocean Ecosystem Dynamics
- UV-VIS hyperspectral sensor with coarser resolution (2 to 7 km)
- Gas correlation IR sensor
- Thermal Infrared sensor

Atmospheric Science Questions & Measurements

1. What are the temporal and spatial variations of **emissions of gases and aerosols** that are important for air quality and climate?
2. How do **physical, chemical, and dynamical processes** determine tropospheric compositions and air quality over scales ranging from urban to continental, diurnally to seasonally?
3. How does **air pollution drive climate forcing** and how does **climate change affect air quality** on a continental scale?
4. How do we **improve air quality forecasts** and assessments for societal benefit?
5. How do **regional and intercontinental transport** affect local and regional air quality?
6. How do **episodic events**, such as wild fires, dust outbreaks, and volcanic eruptions, affect atmospheric composition and air quality?

Baseline measurements

O3, NO2, CO, SO2, HCHO, CH4, NH3, CHOCHO, different sampling frequencies, 4 km horizontal spatial footprint size at nadir; and
AOD, AAOD, AI, aerosol optical centroid height (AOCH), cloud detection, hourly for SZA<70 and 1 km horizontal spatial footprint size at nadir.

Threshold measurements

CO hourly day and night, and O3, NO2, SO2, hourly for SZA<70, at 8 km horizontal spatial footprint at nadir; AOD hourly (SZA<70) at 2 km.

GEO-CAPE aerosol-atmospheres Science Traceability Matrix as approved by Science Working Group in March 2010

Advantages of Geostationary Observations of Coastal Waters

- Observations analogous to “weather” for coastal waters
  - water quality, primary production, harmful blooms, etc.
- Discriminate **physical** from **biological** forcing
  - Rates of biological and physical processes possible:

    Primary production, photooxidation, transport of materials, etc.
- Study short time scales associated with dynamic coastal processes (tides, wind-driven currents, storm surges, algal blooms)
- More opportunities for cloud-free viewing
- High signal-to-noise at finer spatial resolution (~300m) can be achieved by longer integration time
- Opportunity to monitor hazardous events on high frequency time scales (oil slicks, HABs, etc.)

GEO-CAPE Oceans STM

Draft v.2.7 - March 24, 2010

Science Focus	Science Questions	Approach (Maps to Science Question)	Measurement Requirements	Instrument Requirements	Platform Requirem.	Ancillary Data Requirem.
Short-Term Processes **Land-Ocean Exchange** **Impacts of Climate Change & Human Activity** **SYNERGY** **Impacts of Airborne-Derived Fluxes** **Episodic Events & Hazards**	**1** How do short-term coastal and open ocean processes interact with and influence larger scale physical, biogeochemical and ecosystem dynamics? (OBB1) **2** How are variations in exchanges across the land-ocean interface related to changes within the watershed, and how do such exchanges influence coastal and open ocean biogeochemistry and ecosystem dynamics? ‡ (OBB1 & 2) **3** How do natural and anthropogenic changes including climate-related forcing impact coastal ecosystem biodiversity and productivity? ‡ (OBB1, 2 & 3) **4** How do airborne-derived fluxes from precipitation, fog and episodic events such as fires, dust storms & volcanoes significantly affect the ecology and biogeochemistry of coastal and open ocean ecosystems? (OBB1 & 2) **5** How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone? (OBB4)	**PRODUCTS** Standing Stocks: Aquatic chlorophyll a, POC, DOC, PIC, DIC*, inherent & apparent optical properties, total suspended matter, phytoplankton biomass*, pigments* and key functional groups, terrigenous DOC*, & black carbon*. Rate Measurements: Aquatic primary productivity, respiration*, air-sea CO2 fluxes*, photooxidation, phytoplankton fluorescence responses*, phytoplankton vertical migration*, net community production of DOC* and POC*, and other associated trophic responses* Hazards: Aquatic HABs, petroleum-derived hydrocarbons, and other pollutants*. ***Products not currently derived from ocean color observations.** Targeted, high-frequency, episodic event-based monitoring and evaluation of tidal and diurnal variability of Standing Stocks, Rate Measurements and Hazards from river mouths to the coastal ocean (and lakes). [1 2 4 5] Routine sampling of seasonal and interannual variations in the Standing Stocks, Rate Measurements and Hazards for estuarine and continental shelf regions with linkages to open-ocean processes at appropriate spatial scales. [2 3 5] Observe coastal region at sufficient spatial scales to resolve near-shore processes, coastal fronts, eddies, and track carbon pools and pollutants. [1 2 5] Integrate GEO-CAPE observations with field measurements, models and other satellite data: 1. To derive coastal carbon budgets and determine whether coastal ecosystems are sources or sinks of carbon to the atmosphere [1 2] 2. To quantify the responses of coastal ecosystems and biogeochemical cycles to river discharge, land use change, airborne-derived fluxes, hazards and climate change. [1 2 3 4 5] 3. To estimate fishery yields, extent of oxygen minimum zones, and ecosystem health (including ocean acidification). [3 5]	Water-leaving radiances in the near-UV, visible & NIR for separating absorbing & scattering constituents & chlorophyll fluorescence Product uncertainty TBD **Temporal Resolution:** *Targeted Events:* • Threshold: 1 hour • Goal: 0.5 hour *Routine Coastal U.S.:* • Threshold: ≤3 hours • Goal: 0.5 hour *Regions of Special Interest (RSI): Threshold: 1 RSI 3 scans/day* • Goal: multiple RSI 3 scans/day *Other Coastal N. & S. America 50°N to 45°S:* • Threshold: 4 times/yr • Goal: ≤3 hours **Spatial Resol. (nadir):** • Threshold: 375 x 375 m • Goal: 250 x 250 m **Field of Regard for Ocean Color Retrievals:** 50°N to 45°S; 162.5°W to 32.5°W **Coastal Coverage:** width from coast to ocean: • Threshold: 375 km • Goal: 500 km RSI: Amazon & Orinoco River plumes, Peruvian upwelling, Cariaco Basin, Bay of Fundy, Rio Plata, etc. (TBD) **Intelligent Payload Module:** Near Real-Time satellite data download from other sensors (GOES, etc.) for on-board autonomous decision making: (TBD) • To bypass scanning mostly cloudy scenes; Targeting events (e.g., HABs)	**Spectral Range:** Hyperspectral UV-VIS-NIR • Threshold: 345-900 nm; 3 SWIR bands 1245, 1640, 2135 nm • Goal: 340-1100 nm; 3 SWIR bands 1245, 1640, 2135 nm **•Spectral Resolution:** • Threshold: UV-VIS: 0.5 nm FWHM; NIR: 1 nm; SWIR: 20-50 nm • Goal: UV-VIS: 0.25 nm FWHM; NIR: 0.5 nm; SWIR: 20-50 nm - Retrieval of NO_2 and O_2 A-band for atm. corrections? (TBD) **Signal-to-Noise Ratio (SNR):** • Threshold: 1000:1 for 10 nm FWHM (380-800 nm); 600:1 for 40 nm FWHM in NIR; 300:1 to 100:1 for SWIR bands (20-50nm FWHM) • Goal: 1500:1 for 10 nm (380-800 nm); 600:1 for 40 nm FWHM in NIR; 300:1 to 200:1 for SWIR bands (20-50nm FWHM); 400:1 NO_2 band (TBD) see Measurement Requirements for Temporal & Spatial Resolutions and Field of View. **Field of Regard:** • ±9° N to S & E to W imaging capability from nadir for Lunar & Solar Cals. **Pointing Stabiliazation** • Threshold: <25% pixel size during single exposure • Goal: <10% pixel size during single exposure **Non-saturating detector array(s) at Lmax** **On-board Calibration:** • Monthly Lunar Calibration at ≤7° phase angle • Solar Calibration (TBD) **Polarization:** <0.5% **Relative Radiometric Precision:** • Threshold: 1% through mission lifetime • Goal: 0.5% through mission lifetime **Mission lifetime:** Threshold: 3 years; Goal: 5 years **Pre-launch characterization:** to achieve radiometric precision above on orbit **Solar Zenith Angle Sensitivity:** Threshold: ±70°; Goal: ±75°	Geostationary orbit to permit sub-hourly observations of coastal waters adjacent to the continental U.S., Central and South America Storage and download of full spatial data and spectral data.	Western hemisphere data sets from models, missions, or field observations: **Measurement Requirements** (1) Ozone (2) Total water vapor (3) Surface wind velocity (4) Surface barometric pressure (5) NO2 concentration (6) Vicarious calibration & validation - coastal (7) Full prelaunch characterization **Science Requirements** (1) SST (2) SSH (3) PAR (4) UV (5) MLD (6) CO2 (7) pH (8) Ocean circulation (9) Tidal & other coastal currents (10) Aerosol & dust deposition (11) run-off loading in coastal zone (12) Wet deposition in coastal zone **Validation Requirements** Conduct high frequency field measurements and modeling to validate GEO-CAPE retrievals from river mouths to beyond the edge of the continental margin.

‡ Climate change-related science questions

GEO-CAPE Science Questions are traceable to NASA's OBB Advanced Planning Document ….

* Coverage area within field-of-view (FOV) includes major estuaries and rivers such as Chesapeake Bay & Lake Pontchartrain/Mississippi River delta, e.g., the Chesapeake Bay coverage region would span west to east from Washington D.C. to several hundred kilometers offshore (total width of 375 km threshold).

Geo-CAPE Ocean Data Products 1

Mission Critical Products (drive requirements; algorithms exist)

- Spectral remote sensing reflectances / Water-leaving radiances
- Chlorophyll-a
- Primary Production
- Particulate Organic Carbon
- Dissolved Organic Carbon
- Particulate Inorganic Carbon
- Total Suspended Matter
- Absorption coefficients of Colored Dissolved Organic Matter, Particles & Phytoplankton
- Particle backscatter coefficient
- Light attenuation coefficient at 490nm; Euphotic depth
- Photosynthetically Available Radiation
- Fluorescence Line Height
- Phytoplankton Carbon (experimental)
- Trichodesmium
- Harmful Algal Bloom detection & magnitude

- Aerosol and other atmospheric products for atmospheric corrections

Geo-CAPE Ocean Data Products 2

Highly Desirable Products (experimental products - TBD)

- Particle size distributions & composition
- other plant pigments (carotenoids, photoprotective, photosynthetic)
- Functional/taxonomic group distributions
- Phytoplankton physiological properties
- Vertical migration detection
- Net Community Production
- Export production
- Respiration
- Air-Sea CO_2 fluxes
- pCO_2(aq)
- Terrigenous Dissolved Organic Carbon
- Petroleum detection and thickness
- Photooxidation

- Data will likely be available in similar formats as SeaWiFS & MODIS data distributed by the NASA Ocean Biology Processing Group.
- Direct broadcast - TBD
- Latency - near-real time likely

Geo-CAPE Ocean Requirements-1

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		Threshold	Goal
Spatial Resolution	nadir (m)	375 x 375 m	250 x 250 m
Temporal Resolution	Routine U.S. Coastal Waters	≤3 hours	0.5 hour
	Targeted Events	1 hour	0.5 hour
	Regions of Special Interest (RSI)	single RSI 3 scans/day	multiple RSI 3 scans/day
	Other Coastal N. & S. America 50°N to 45°S	seasonal; 4 times/yr	≤3 hours
Coastal Coverage	width from coast to ocean	375 km	500 km
US Coastal Waters (US CW)	Includes bays, estuaries, lakes and rivers	US CW 375 km wide, Great Lakes and major rivers*	US CW 500 km wide, Great Lakes and major rivers
Regions of Special Interest (RSI)		Amazon & Orinoco River plumes, Peruvian upwelling, etc.	All other CW from 45 S to 50 N latitude within 300 km from shore

* Coverage area width includes major estuaries and rivers such as Chesapeake Bay & Lake Pontchartrain/ Mississippi River delta, e.g., the Chesapeake Bay coverage region would span west to east from Washington D.C. to several hundred kilometers offshore (total width of 375 km minimum).

Geo-CAPE Ocean Requirements-2

Draft v.2.7 - March 24, 2010

		Threshold	Goal
Spectral Range	Hyperspectral UV-VIS-NIR; Multispectral SWIR	345-900 nm; SWIR: 1245, 1640 & 2135 nm	340-1100 nm; SWIR: 1245, 1640 & 2135 nm
Spectral Resolution		UV-VIS: 0.5 nm; NIR: 1nm SWIR: 20-50nm	UV-VIS: 0.25 nm; NIR: 0.5 nm; SWIR: 20-50nm
Signal-to-Noise Ratio (SNR)	For Ocean Scenes at specified Ltyp:	UV-VIS: 1000:1 (10nm bands); NIR: 600:1 (40nm); SWIR: 300 to 100:1 (20-50nm bands)	UV-VIS: 1500:1 (10nm bands); NIR: 600:1 (40nm); SWIR: 300 to 200:1 (20-50nm bands)
Field of Regard Ocean Color		~50°N to 45°S ~155°W to 35°W	same as threshold
Pixel pointing stability		<25% pixel size during single exposure	10% pixel size during single exposure
Relative Radiometric Precision	UV-VIS-NIR & SWIR	1% through mission lifetime	0.5% through mission lifetime
Polarization		<0.5%	same as threshold
Lifetime Design	Class B	3 years	5 years

Geo-CAPE Ocean Approach

- Survey mode for evaluation of diurnal, seasonal and interannual variability
  - *U.S. coastal waters*
  - *Regions of special interest*
  - *All other coastal waters from 50°N to 45°S*
- Targeted observations of high-frequency and episodic events including evaluation of tidal and diurnal variability
- High spatial resolution to resolve near-shore processes, fronts, eddies, and track carbon pools and pollutants
- Integrate Geo-CAPE observations with field measurements, models and other satellite data:
  - *To **derive coastal carbon budgets** and determine whether coastal ecosystems are sources or sinks of carbon to the atmosphere.*
  - *To **quantify the responses of coastal ecosystems and biogeochemical cycles** to river discharge, land use change, airborne-derived fluxes, hazards and climate change.*
  - *To estimate **fishery yields**, extent of **oxygen minimum zones**, and **ecosystem health** (including ocean acidification).*

Geo-CAPE Coastal Waters Science & Applications

- To quantify the response of marine ecosystems to short-term physical events, such as passage of storms and tidal mixing.
- To assess the importance of high temporal variability in coastal-ecosystem models.
- To monitor biotic and abiotic material in transient surface features, such as river plumes and tidal fronts.
- To detect, track and predict the location of sources of hazardous materials, such as oil spills, waste disposal, and harmful algal blooms.
- To detect floods from various sources, including river overflows.

Societal benefits from GEO-CAPE oceans mission

- Prediction of fisheries yield through improvement of models and model forecasting.
- Detection and tracking of hazards that relate to human health.
- Link data to models and decision-support tools and processes.
  e.g., to predict the occurrence and extent of hypoxic regions (“dead zones”)
- Measurements of response parameters (i.e., chlorophyll-a and water clarity) to support water quality assessments, watershed protection management and development of nutrient Total Maximum Daily Loads.

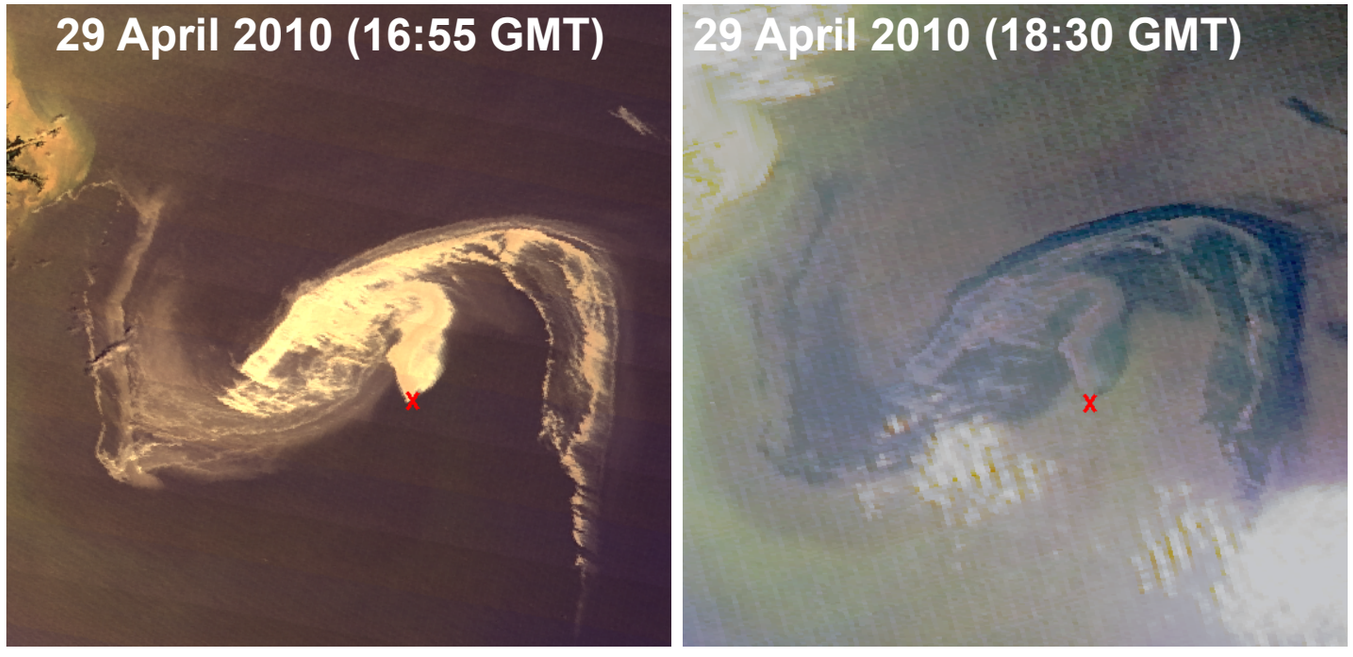
Episodic Events & Hazards

What cannot be achieved with existing sensors but possible with Geo-CAPE?

- Estimate surface oil film thickness (with multi-angle illumination)
- Study vertical migration of harmful and non-harmful algae
- Trace origin and evolution of hazardous events more effectively
- Assess impacts more precisely (e.g., changes in species)

Changes in color contrast are due to changes in solar/viewing angles

Oil spill volume assessment



HAB detection from diurnal vertical migration of the toxic Karenia brevis